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Asymmetrical Fifteen Level Inverter using Equal Phase Angle and Half Height Method for Switching Angle Computation

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ABSTRACT: There is an increased demand for MLI in the power industry. In the recent years various topologies have been used by researchers to produce alternatives for wide range of applications. The recently introduced topologies through light on reduction in overall part count when compared to conventional topologies. In this paper 3 different input DC sources in the ratio of 1:2:4 are used to produce fifteen levels of output. The circuit is simulated to get 230V of output voltage using MATLAB/Simulink. A simplified fifteen level inverter is selected here and switching angles are calculated using equal phase method and half height method.

KEYWORDS: Fifteen level inverters, Total Harmonic distortions, MATLAB, Switching techniques.

I. INTRODUCTION

Conversion of DC to AC power is of prime importance in electric power system. Modern devices like air conditioners, induction heaters, variable frequency drives, compensator, AC transmission systems require DC to AC power conversion [1,2] A sound heat sink design and layout design is essential as the switching frequencies are high that will result in increase in switching losses and EMI problems[3].These problems can be reduced using resonant converters but design of these resonant type inverters is complex and quite costly.

Multilevel converters are electronic systems that synthesize a preferred output voltage from various input DC voltages. MLI's can achieve various levels of voltages at the output as a step-wise waveform by a combination of power diodes, voltage sources and multiple active switches[4].Hence for high power applications MLI serve as the best option. It has been observed that MLI have greater advantage compared to conventional inverters due to low voltage stress across the switches, low switching loses and there is less electromagnetic interference. The various dc-ac power conversion devices based on voltage source can be classified as two level voltage source and multilevel inverters. The commonly used MLI are Diode-clamped, Cascaded H-bridge and flying capacitors. The Diode clamped and flying capacitors have shown limitations in capacitor voltage balancing whereas Cascaded H-bridge show a lot of promise in solving the said problem[5-8]. By using many H-bridges in series a multilevel stepped waveform can be generated[9-10]. The cascaded H-bridge inverters consists power conversion cells in series with combination of switches and capacitors[11]. In CHBMLI voltage cells are connected across H-bridge cells whereas the capacitors and diodes are eliminated. There are two types of CHMLI i.e, symmetric CHMLI and asymmetric CHMLI. In symmetric CHMLI the topologies have equal voltage sources whereas asymmetric topologies have unequal DC voltage sources[12].

II. PROPOSED WORK

In this work a new 15 Level MLI with 7 switches using 3 dc sources in the ratio 1:2:4 has been implemented. The input DC voltage ratios must be in such a way that all output voltage levels can be generated.The switching angle calculations is done by Half Height Method. A new topology is proposed that can produce 15 level o/p voltage with less number of switching modules. A Polarity Generator and a Level Generator can be housed in this module. The required levels are started by the level generator and thereafter these levels are transformed into positive and negative levels by the polarity generator[8]. 15 level o\p voltages are generated using this proposed MLI. They are **V_{dc}6, V_{dc}, 5V_{dc}, 4V_{dc}, 3V_{dc}, 2V_{dc}, V_{dc}, 0V_{dc}, -1V_{dc}, -2V_{dc}, -3V_{dc}, -4V_{dc}, -5V_{dc}, -6V_{dc}, -V_{dc}.**

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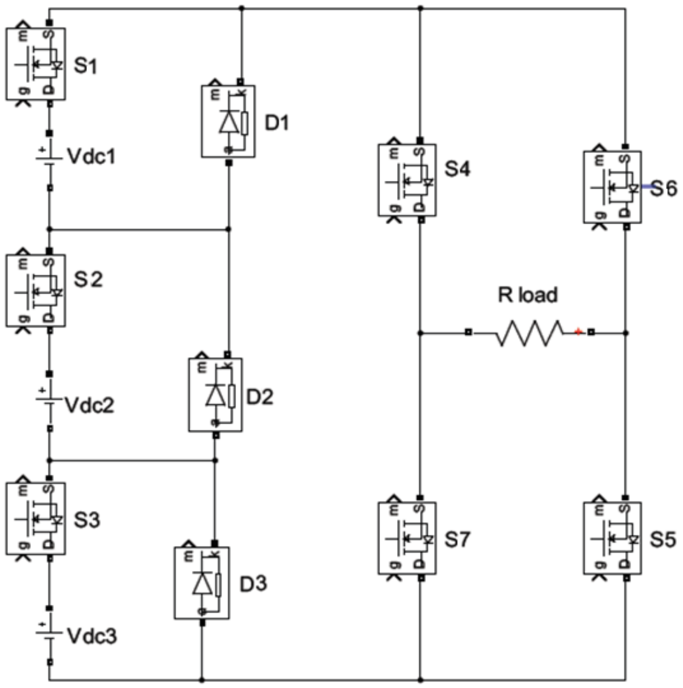

Fig. 1: Circuit diagram of 15 Level Inverter

Table 1:Truth Table of Switching Sequence

V_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7
V_{dc}	1	1	1	1	1	0	0
$6V_{dc}$	0	1	1	1	1	0	0
$5V_{dc}$	1	0	1	1	1	0	0
$4V_{dc}$	0	0	1	1	1	0	0
$3V_{dc}$	1	1	0	1	1	0	0
$2V_{dc}$	0	1	0	1	1	0	0
V_{dc}	1	0	0	1	1	0	0
$0V_{dc}$	0	0	0	1	0	1	0
$0V_{dc}$	0	0	0	0	1	0	1
$-1V_{dc}$	1	0	0	0	0	1	1
$-2V_{dc}$	0	1	0	0	0	1	1
$-3V_{dc}$	1	1	0	0	0	1	1
$-4V_{dc}$	0	0	1	0	0	1	1
$-5V_{dc}$	1	0	1	0	0	1	1
$-6V_{dc}$	0	1	1	0	0	1	1
$-V_{dc}$	1	1	1	0	0	1	1

A cascaded H-bridge MLI uses three separate dc sources and 16 switches whereas this proposed 15 level inverter can work with only seven switches and 3 DC sources. Fifteen levels Cascaded H-bridge [4] voltage source inverter designed and eliminated harmonics in MLI. It has been observed that using a 15 level CHB VSI with 12 switches can eliminate harmonics in MLI. In this experimental work a inverter with 7 switches and 3 DC sources is proposed to reduce THD and obtain a merely sinusoidal waveform. Also this proposed topology uses less number of switches when compared to diode clamped MLI(more diodes and switches) , cascaded MLI, flying capacitor MLI. Fig. 2 represents the circuit diagram of the 15 level Inverter which has three cells, each cell having three diodes and switches in addition to the H-bridge. The switching sequence to obtain the 15 levels of output voltage is tabulated in table 1. The input DC voltage is given in the ratio of 1:2:4. Switching angles are calculated using two different methods; Equal Phase Angle and Half Height Method. The THD of output voltage using both the said methods is obtained.

III.CONTROL TECHNIQUES

Switching angle is the moment of the voltage level change at the output. For an m-level waveform there are 2(m-1) switching angles are needed. We call them as $\alpha_1, \alpha_2, \alpha_3 \ldots\ldots \alpha_{m-2}, \alpha_{m-1}$. Since the sine wave is a symmetrical waveform, the negative half cycle is centrally symmetrical to its positive half cycle; and the waveform of the second quarter period is mirror symmetrical to the waveform of its first quarter period. So, we call the switching angles in the first quadrant period i.e., 0º-90 º as main switching angles.
Main Switching Angles in the first quarter of the sine wave (i.e., 00 to 90)**:**

$\alpha_1, \alpha_2, \alpha_3, \ldots\ldots\ldots, \alpha_{(m-1)/2}$ (1)

The switching angles at 90º to 180º of the sine wave are:

$\alpha_{\frac{m+1}{2}} = \pi - \alpha_{\frac{m-1}{2}}, \pi - \alpha_{\frac{m-2}{2}}, \ldots\ldots\ldots.\pi - \alpha_1$ (2)

The switching angles at 180º to 270º in the third quadrant of the sine wave are

$\alpha_m = \pi + \alpha_1, \ldots\ldots.., \pi + \alpha_{(m-1)/2}$ (3)

whereas the switching angles at 270º to 360º in the fourth quadrant are

$\alpha_{(3m-1)/2} = 2\pi - \alpha_{\frac{m-1}{2}}, \ldots\ldots., 2\pi - \alpha_1$ (4)

From the above analysis it was concluded that we need to determine only the main switching angles (i.e., from 0º to 90º), the other switching angles (i.e., from 90º to 360º) can be obtained from the main switching angles in the first quadrant. The main switching angles of the proposed inverter are determined from the following methods.

3.1 Equal Phase Angle Method: In the EP method the switching angles are distributed averagely in the range 0-Π.The main switching angles are obtained by the formula given below:

$\alpha i = \frac{180*i}{N}$where i=1, 2,………… (m-1)/2…………(5)

3.2 Half Height method: In most of the methods the arrangement of switching angles are in a modest manner and the output waveform is not in form of a sine wave. The Half Height Method is used to define new switching angles as per the sine function. The following formulae can be used to determine the switching angles.

$\alpha_i = \sin^{-1}[(2i-1)/m-1)]$

wherei=1, 2,............(m-1)/2 ....(6)

Table 1:Switching Angles of EP Method

α_i	Switching Angles
α_0	0
α_1	12
α_2	24
α_3	36
α_4	48
α_5	60
α_6	72
α_7	84
α_8	96
α_9	108
α_{10}	120
α_{11}	132
α_{12}	144
α_{13}	156
α_{14}	168
α_{15}	180

Table 2:Switching Angles of HH Method

α_i	Switching Angles
α_0	0
α_1	4.096
α_2	12.373
α_3	20.9248
α_4	30
α_5	40.005
α_6	51.786
α_7	68.213
α_8	90
α_9	111.786
α_{10}	128.213
α_{11}	139.99
α_{12}	150
α_{13}	159.075
α_{14}	167.626
α_{15}	175.904

3.3 Simulation of 15-level inverter:

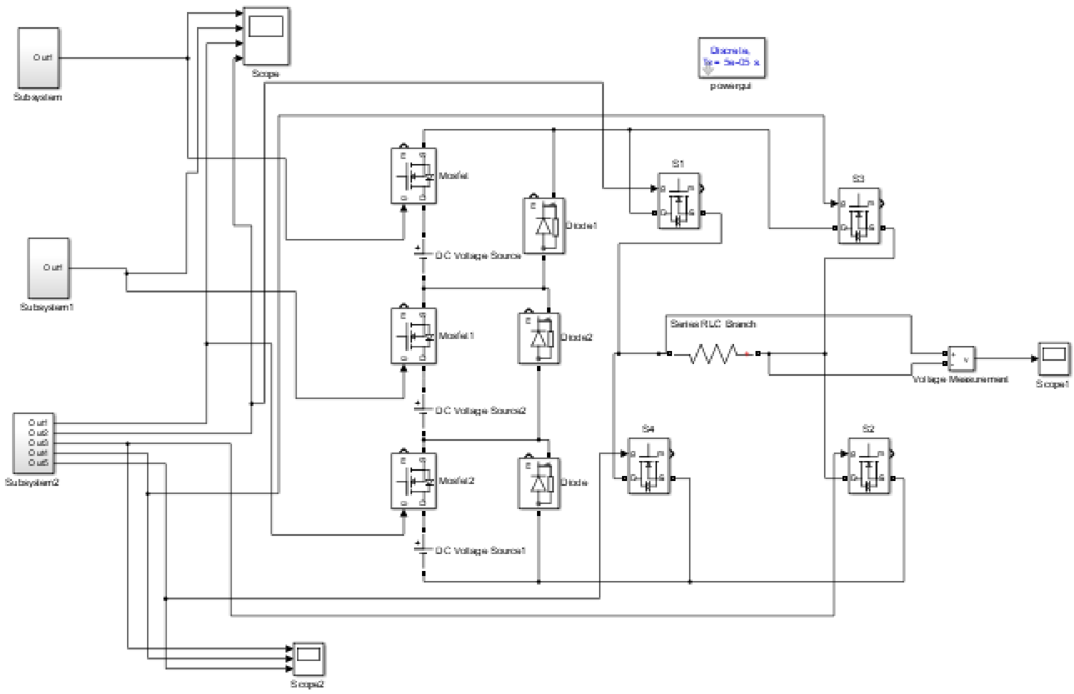

Fig. 2: simulation of 15 Level Inverter

Specification of circuit:

V1 = 45V
V2 = 90V
V3 = 180V
P = 2.22 KW
R load : R = 22.2 Ω

RL load : R = 17.81 Ω
L = 42.53 mH

IV. RESULT AND DISCUSSION

The simulation for 15 level multilevel inverter is carried out using MATLAB/Simulink and the simulated circuitmodel is shown in fig . The input DC voltages sources for inverter are assigned with the magnitudes 45V, 90V and 180V satisfying the ratio 1:2:4. Figure 3 shows the Switching pulses generated for one cycle. The simulated output voltage waveform by EP method is shown in figure 3.1 and the THD analysis by EP method is seen in figure 3.2 Output voltage waveform and the respective THD analysis by Half-Height method is shown in figure 3.3 and 3.4.

From figure 3.5 it is observed from the graphs plotted using data from MATLAB/Simulink that using Half Height Method there is not much variation in % THD for different values of Resistive and Inductive loads. Using Equal Phase Angle Method there is drastic drop in the % THD for different Inductive Loads between 0mH and 50mH. Whereas when the Inductive Load is increased from 50mH to 100mH there is a just a slight variation in the % THD.

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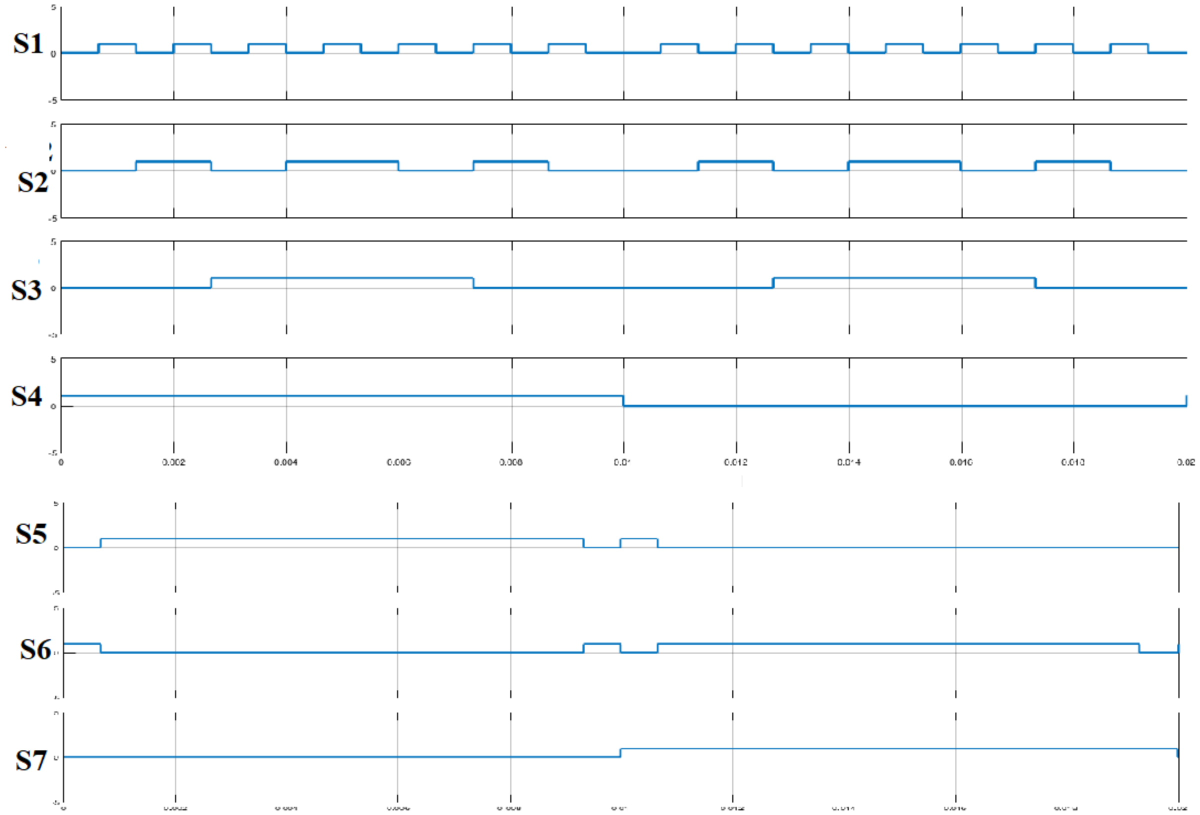
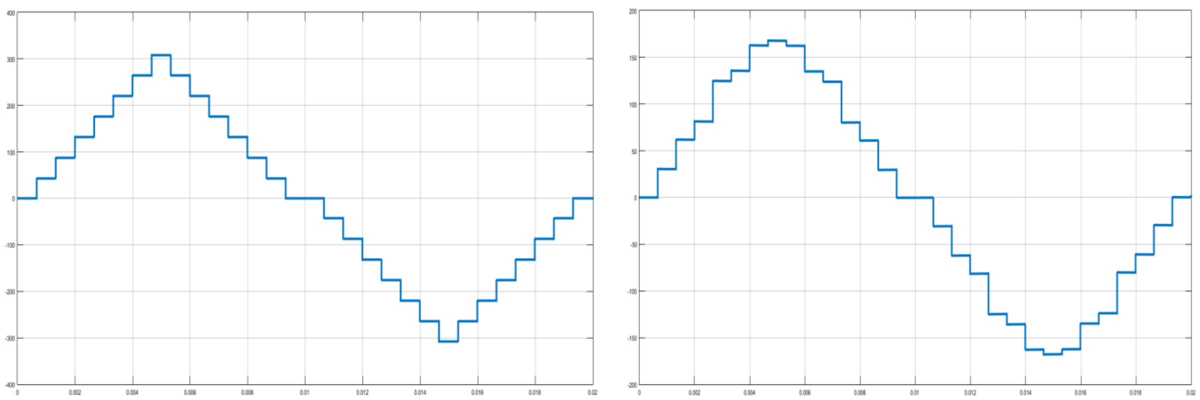


Fig 3: Switching pulses for one cycle



R Load RL Load

Fig 3.1: output voltage waveform by EP method

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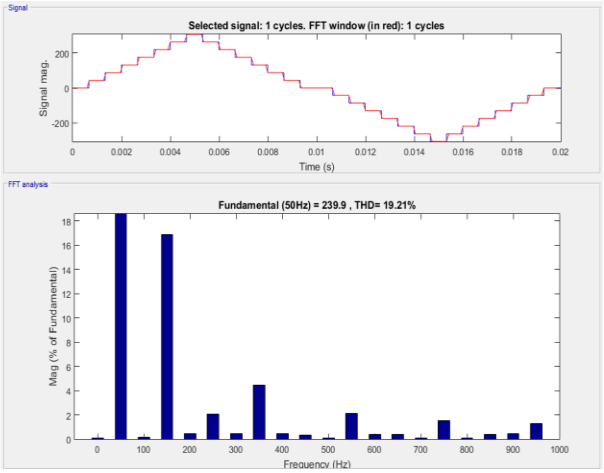
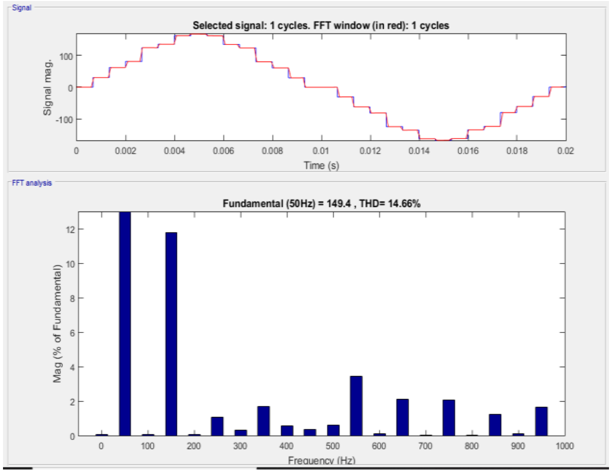
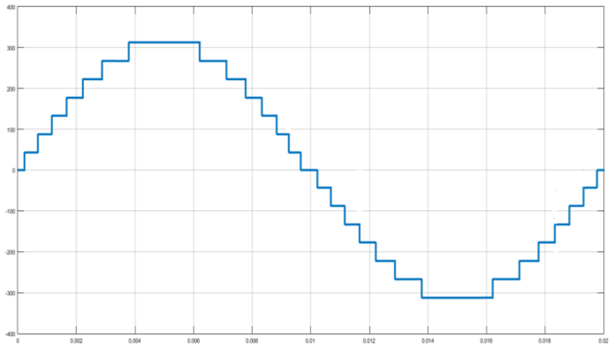


R Load

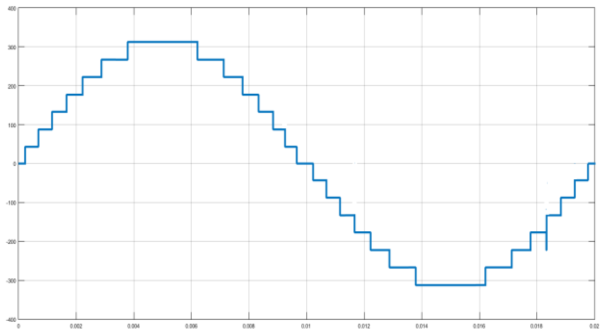


RL Load

Fig 3.2: THD analysis by EP method

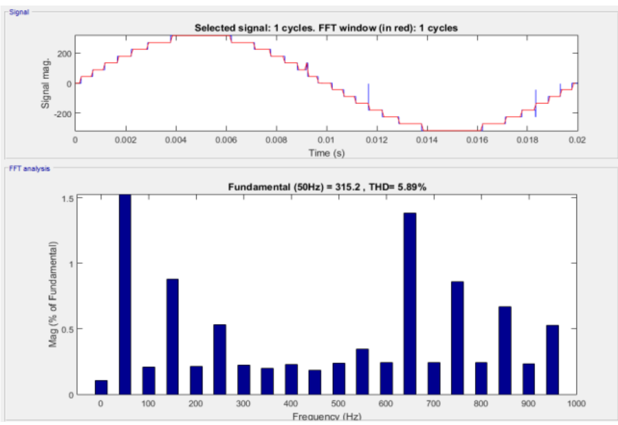


R Load

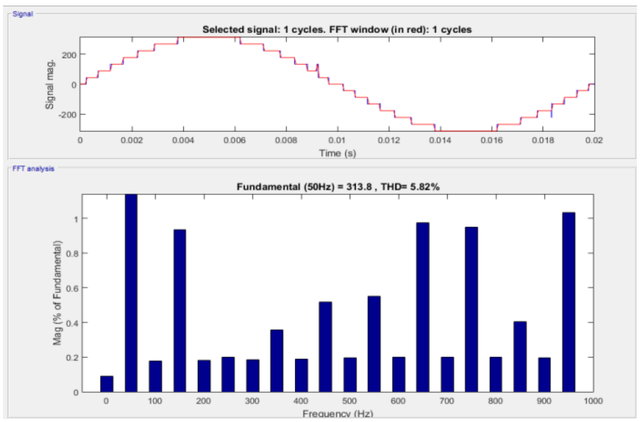


RL Load

Fig 3.3: Output voltage waveform by Half-Height method



R Load



RL Load

Fig 3.4: THD analysis by Half-Height method

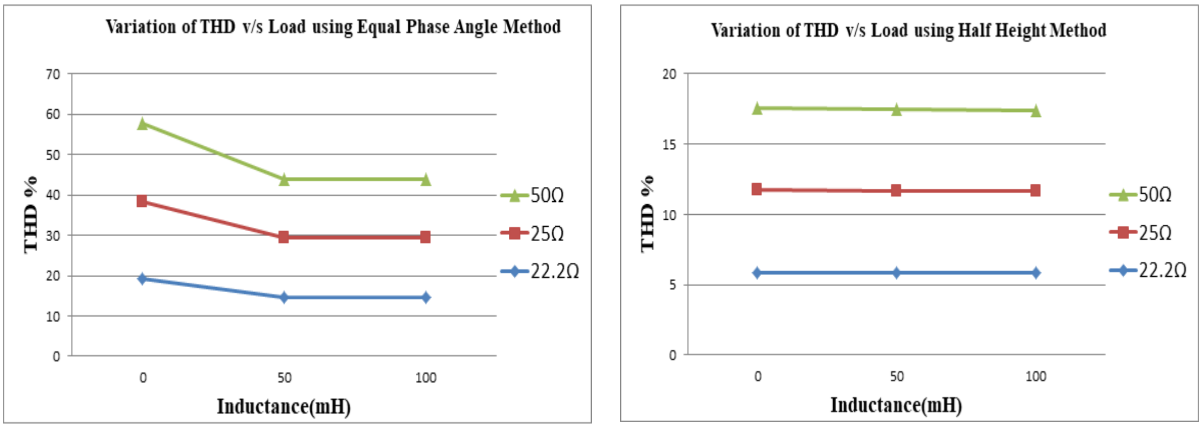
Table 3: Variation of THD for Different Loads

Using Equal Angle Method

	R= 22.2 Ω	R= 25 Ω	R= 50 Ω
L = 0 mH	19.21	19.23	19.25
L = 50 mH	14.67	14.65	14.6
L = 100mH	14.66	14.68	14.62

Using Half Height Method

	R=22.2 Ω	R= 25 Ω	R= 50 Ω
L = 0 mH	5.89	5.88	5.83
L = 50 mH	5.83	5.80	5.83
L = 100mH	5.83	5.86	5.80



(a)Using Equal Angle Method **(b)Using Half Height Method**

Fig. 3.5 : Variation of THD v/s Load

VI.CONCLUSION

The proposed MLI uses only 7 switches to give 15 level output. The design and simulation of 15-level Asymmetrical Multi-level inverter for different values of Resistive load and Inductive load is simulated and analyzed. Among the two control techniques, Half-Height method gives less THD compared to Equal Phase Angle Method. It is observed that the obtained % THD with Half-Height method is lesser that that of Equal Phase Angle method for different Loads which satisfies IEEE519 standards. In this study, a fifteen level asymmetric cascaded multilevel inverter is proposed. It generates sinusoidal waveform and generates high voltage and it improves the performance of cascaded multilevel inverter. Also there are less switching losses and the total harmonic distortion also reduced.

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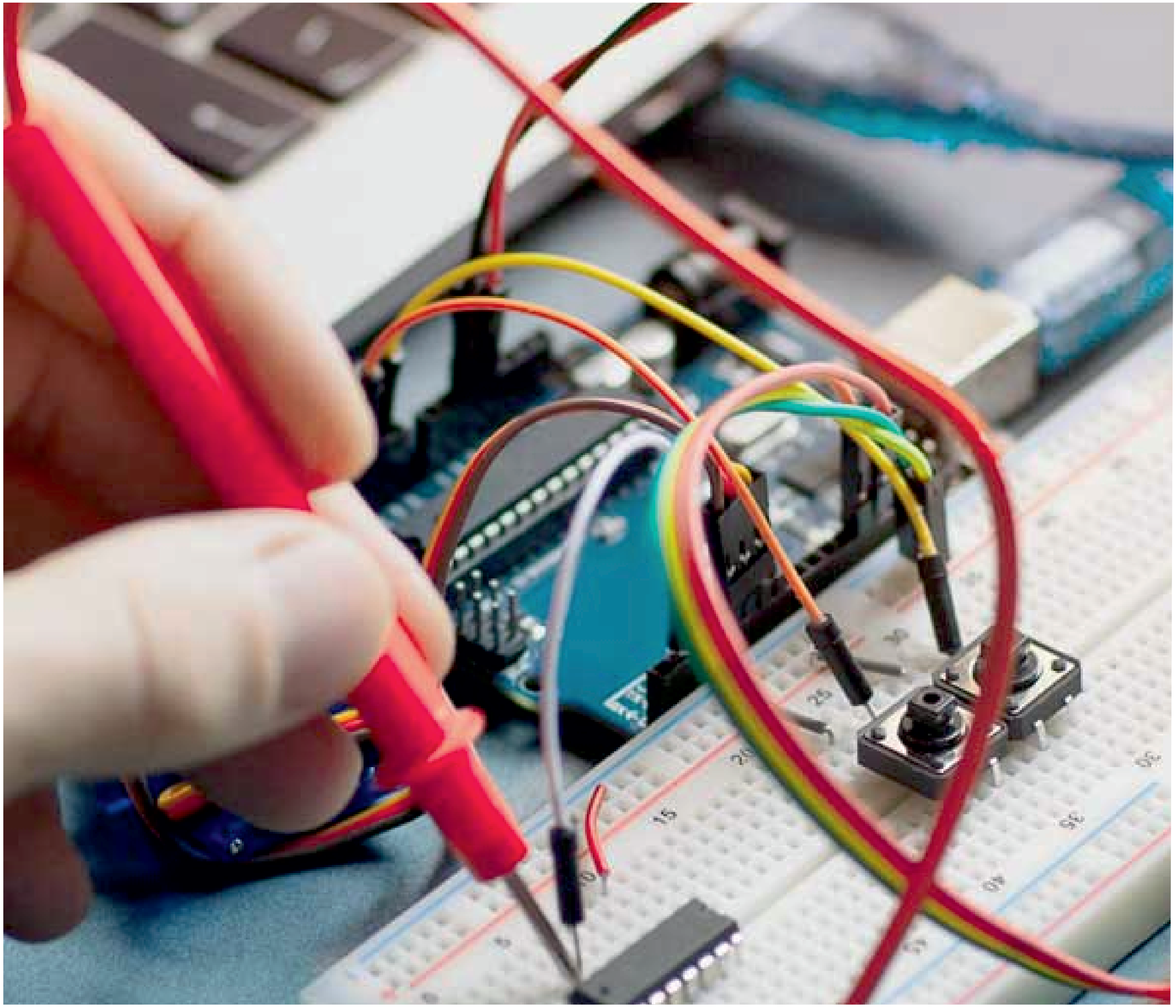

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